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A STUDY OF THE EASTERN BLUEBIRD AT THE HOLDEN ARBORETUM, LAKE COUNTY, OHIO

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Abstract

A study of the nesting of the Eastern Bluebird at the Holden Arboretum in Lake County, Ohio, was conducted from 1965 through 1980. Emphasis was placed on causes of nest failure and methods used to control them. The 16-year volunteer effort contributed to an increase in the Eastern Bluebird population at the Arboretum. Some information on the nesting of Tree Swallows was also gathered during the study.



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Fig. 1: Holden Arboretum in August 1980

Introduction

In 1965, a volunteer effort was begun to increase the population of the Eastern Bluebird (*Siala sialis*) at the Holden Arboretum (hereafter referred to as the Arboretum), in Kirtland and Mentor Townships, Lake County, Ohio.

A previous effort had been made at this location to provide additional nesting sites for bluebirds by a local volunteer, Paul Smith, who built and placed 230 bluebird boxes on the property. Only eight pairs of bluebirds, however, nested in this area in 1965. At that time, House Wrens (*Troglodytes aedon*) occupied 49 boxes and House Sparrows (*Passer domesticus*) occupied 134.

The boxes, located in 14 areas either in meadows or plantings along hedgerows or woods, were unpainted with side openings and were placed approximately 4 to 5 ft above the ground on metal fence posts. (A few were placed 6 ft high; one was only 2 ft above the ground.)

Project Bluebird was begun in 1965 by Virginia Barrus, a local ornithologist and bird bander, as a volunteer program to study the Arboretum bluebird nesting population in an effort to maintain and, if possible, increase it. Prior to the 1965 nesting season she cleaned and repaired the 230 original boxes.

Although there have been several reports of such efforts to increase bluebird populations (Kibler, 1969; Laskey, 1939; Pinkowski, 1979; Musselman, 1935) none covered such a long period of time, 16 years (1965-80), as in this study.

Because of a significant number of Tree Swallows (*Iridoprocne Bicolor*) nesting in the boxes, they have been included in this study.

The Study Area

The Holden Arboretum consists of 5 sq mi (approximately 2,800 acres) of rolling land in Lake and Geauga Counties (lat 41° 37'N; long 81° 19'W). Elevations (excluding the highest point, Little Mountain) range from 750 to 1,200 ft. (The areas included in this study range from 900 to 1,100 ft.) The area is drained by Stebbins Gulch and Pierson Creek, both of which empty into the East Branch of the Chagrin River which runs through the property. The Arboretum is approximately 27 mi northeast of Cleveland and 2 mi south of Lake Erie.

As the accompanying map (Fig. 4) shows, the area is highly irregular in outline due to private ownership of adjoining properties. Although most of the Arboretum's properties are contiguous, one large area and several small ones are separate.

Fig. 2 Eastern Bluebirds
Nesting Success 1965-1980

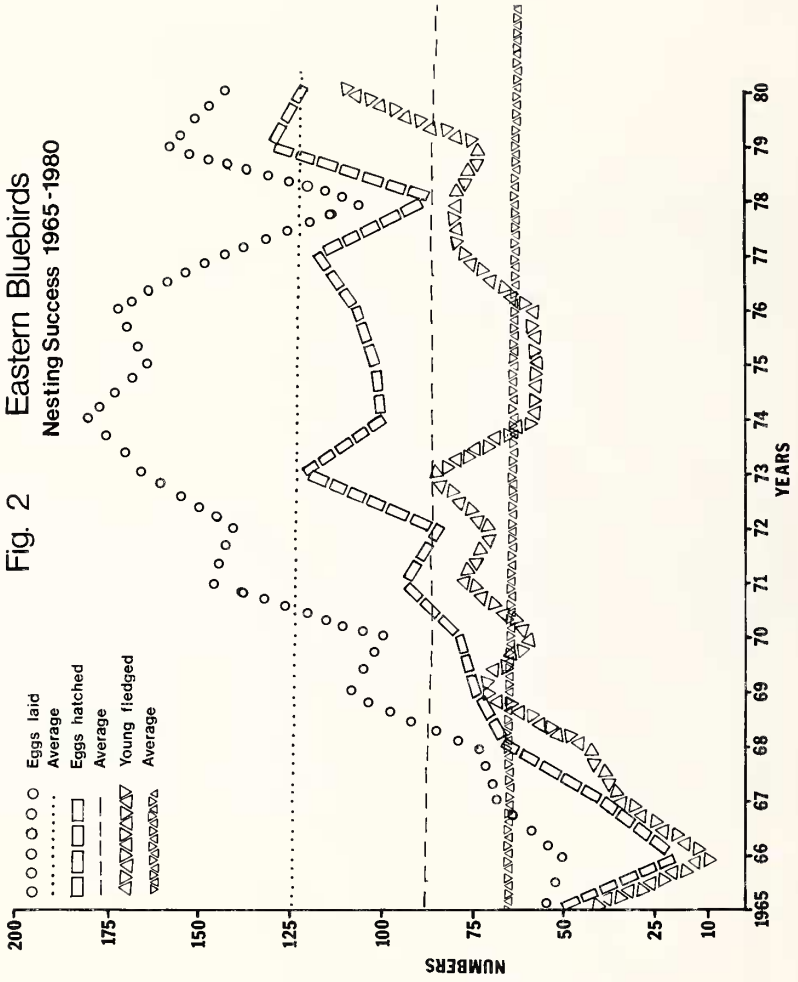
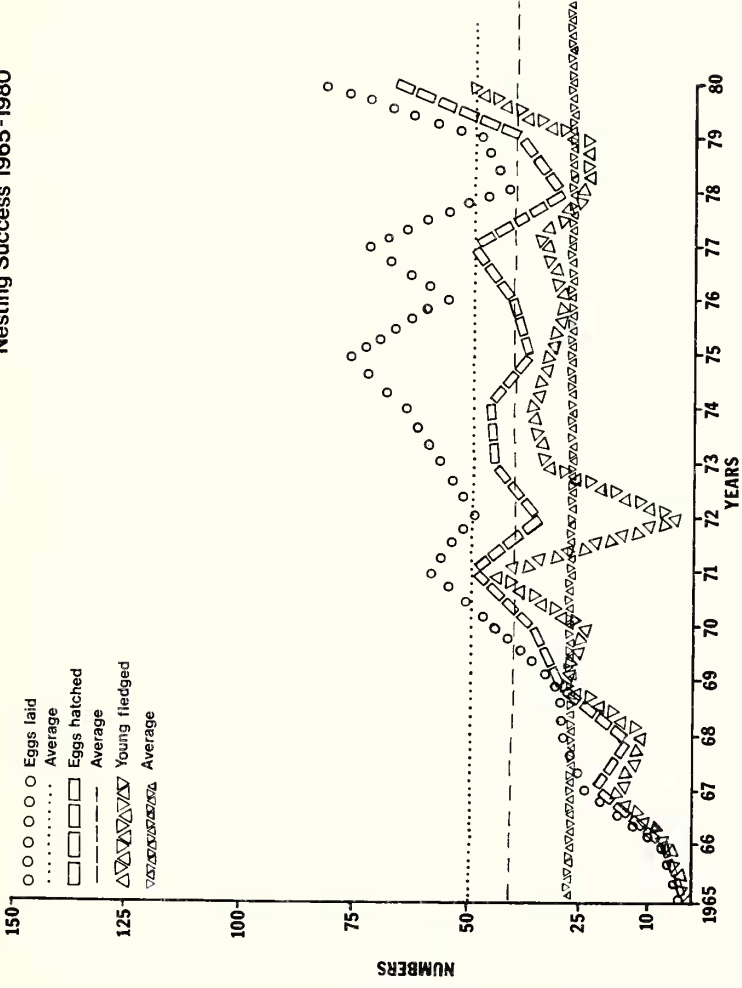
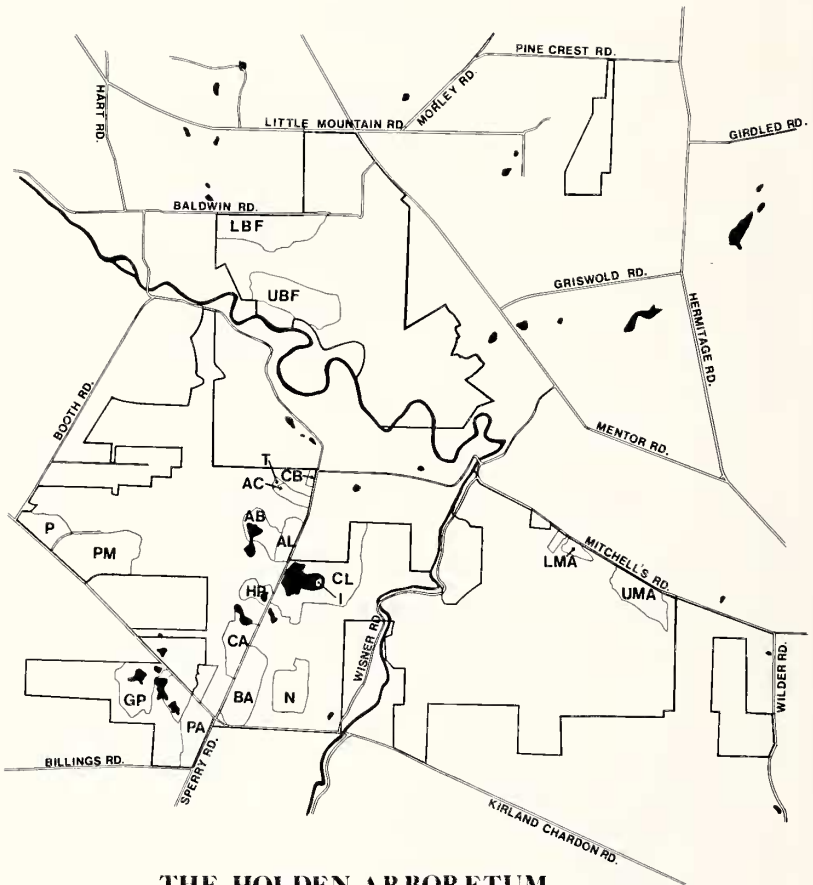


Fig. 3 Tree Swallows
Nesting Success 1965-1980





THE HOLDEN ARBORETUM

Fig. 4: Eastern Bluebird nest box areas at Holden Arboretum. Areas active in 1980: T—Thayer Center; CL—Corning Lake; HP—Heath Pond; CA—Chapin Acres; BA—Bicknell Acres; N—Norweb; GP—Goose Pond; PM—Paul Martin Farm; P—Pines; UMA—Upper Mather Acres; LBF—Lower Baldwin Farm; UBF—Upper Baldwin Farm. Areas discontinued during the study period were: CB—Cooper Building; I—Island in Corning Lake; PA—Park Acres; AC—Around Crabapples; AB—Around Blueberry Pond; AL—Around the Lilacs; LMA—Lower Mather Acres.

At least 1,700 acres are covered by woodland—coniferous, mixed, and deciduous woods, with the latter predominating. There are 18 lakes and ponds, the largest of which is Corning Lake, approximately 20 acres.

The areas included in this study are located either in nurseries or plantings with sufficient open space to meet the needs of bluebirds, or in undeveloped fields. On the map each area is defined by the point at which field meets roadway, woodland, or, in a few cases, an extension of the field which was unsuitable because of competition from other species or heavy human use. Areas which had boxes at the start of the project but which have been phased out, as well as the present (1980) placement of boxes, are shown.

The following is a detailed account of each study area.

Former Areas

Cooper Building (CB). The area in the immediate vicinity of the administrative building contained 10 boxes in 1965, all of which were inhabited by House Sparrows. We removed these prior to the 1967 season.

Island in Corning Lake (I). This area had 10 boxes in 1965. All boxes were removed after the 1967 season due to inaccessibility for monitoring and occupation by House Sparrows.

Park Acres (PA). An area on the southeast corner of Sperry and Kirtland-Chardon Roads contained 10 boxes in 1965 inhabited by House Sparrows. They were removed prior to the 1967 season.

Around Blueberry Pond (AB). Most of this area is covered by deciduous woodland and mature coniferous plantings. Seventeen boxes were placed in small open spaces. There was one successful bluebird nesting in 1967. In 1975 and 1976, bluebird attempts were interrupted by predators and wrens. Otherwise there was no bluebird activity. Black-capped Chickadees (*Parus atricapillus*) successful in 1967 and 1968, were interrupted by wrens or human beings in subsequent attempts. There are several heavily used trails. Boxes were removed gradually until none remained in 1979.

Lower Mather Acres (LMA). This is a small triangular area with an entrance on Mitchell's Mills Road. It is surrounded by deciduous or mixed woods and contains an old barn. To the southeast is Stebbins Gulch. This area was heavily populated by House Wrens. Six bluebird attempts were unsuccessful due to interference by wrens. The original nine boxes were gradually reduced to six by 1975. Five of these were removed before the 1976 season. The last box was removed before the 1980 season.

Around the Lilacs (AL). This area stretches from the Arboretum reception center south along Sperry Road for approximately 1,000 ft to a

property line where it is separated by a fence from an undeveloped field. On the north a double row of white pines (*Pinus strobus*) separates it from the parking area. It extends west from the road for approximately 150 ft where it meets deciduous woods and groves of pine and aspen. A small pond and brook separate the lilac collection in the larger northern portion from an open area containing scattered trees and shrubs and continuing to the west where there is another pond.

The original 17 boxes were gradually reduced to 14 by 1969. Nine were removed prior to the 1970 season in an effort to reduce House Sparrow and House Wren competition. There were four boxes from 1971 through 1974. In 1979 the last two boxes were removed due to heavy human use of the areas where they were located and continuing House Sparrow activity.

During 10 of the first 12 years of the study one pair of bluebirds nested or attempted to do so. In 1967 and 1969 there were two pairs. Eight broods fledged, the last one in 1974. Of 14 nesting attempts by Tree Swallows only five succeeded, the last one in 1973.

The Crabapple Collection (AC). This area contained 24 boxes in 1965. In an effort to reduce House Sparrow and wren competition, we reduced the number to eight in 1970. As tree growth gradually eliminated open space, this area failed to attract bluebirds except for an open triangle containing three boxes at the extreme northwest bounded on two sides by deciduous woods and on one by crabapples (*Malus*) and hawthornes (*Crataegus*). By 1979 this remaining section (Thayer Center, T on map) contained only one box.

The total AC area almost always attracted one pair of bluebirds, occasionally two. However, prior to 1976, when all but three of the boxes were removed, bluebirds were successful in only three years. From 1976 through 1980, with the exception of 1978 when the nesting was interrupted by House Sparrows, one or two broods fledged each year from the remaining box in section T.

Areas of Continuous Use

Corning Lake (CL). This area surrounds Corning Lake except on the Sperry Road side (Fig. 5). It is almost entirely surrounded by deciduous woodland or hedgerow and contains collections of evergreens, birch (*Betula*), alder (*Alnus*), and hornbeam (*Ostrya*). The open space is broken here and there by maple (*Acer*) and sassafras (*Sassafras albidum*) and there are willows (*Salix*) near the lake. Both islands are covered with dense deciduous growth. Most of the grassy area is mowed.



Fig. 5. Corning Lake Area, Holden Arboretum.

By 1967 the original 29 boxes had been increased to 32. In 1968, we removed eight and relocated seven. Since then the number has been reduced to 19. We eliminated five boxes which attracted House Sparrows and/or wrens and relocated two others.

In this area the number of bluebird pairs varied from two to four with an average of 3.3, and 56 broods fledged. From 1967 through 1980, with the exception of 1977, at least one pair of Tree Swallows nested. In 1970 and 1974 there were four pairs. During one season there were three, and during three seasons, two pairs.

Heath Pond (HP). This small area is almost surrounded by mixed woods. It contains two ponds, two enormous old oaks (*Quercus alba* and *Quercus rubra*) and the Arboretum's rhododendron and azalea collections. In 1965 there were nine houses. By 1971 we had removed all but four in an attempt to reduce wren competition, which appeared to have stopped bluebird attempts to nest. After 1976 there were only three boxes. The first bluebird success in this area was in 1971. Since then at least one brood fledged in 8 of 10 years.

Bicknell Acres (BA). This is a strip of land approximately 500 ft wide and 2,200 ft long on the east side of Sperry Road extending north-northeast from Kirtland-Chardon Road to a low wooded area bordering a



Fig 6. Bicknell Acres, Holden Arboretum.



Fig 7. Chapin Acres, Holden Arboretum.

pond (Fig. 6). The magnolia collection at the north end, which contains two boxes, is surrounded by deciduous woodland except where it meets the road. South of the magnolia collection, deciduous woodland nearly meets the road in three places, leaving two fields which slope to the east for 1,700 ft before they meet the woods. There are six boxes in all.

There was one pair of bluebirds during two of the first six years. From 1971 through 1980 there have been two with the exception of 1976 when there were three pairs. A pair of Tree Swallows nested in this area during four years, including 1979 and 1980.

Chapin Acres (CA). This area is on the west side of Sperry Road (Fig. 7). At the northeastern end is a pond. Deciduous woodland extends from the road along the far edge of the pond, then southerly, coming within 250 ft of the road at the southern end. The evergreen planting which occupies much of the area continues south to Kirtland-Chardon Road. This southern part of the area had boxes which were removed prior to the 1976 season because they attracted House Sparrows and wrens. The one bluebird attempt (1974) failed because of wren interference. Since 1976, there have been seven boxes in the northern section of CA.

There was one pair of bluebirds in 4 of the first 10 years. From 1975 through 1979 there was one pair. In 1980 there were two pairs. At least one pair of Tree Swallows nested in this area every year since 1966.

The Paul Martin Farm (PM). This area is bounded by deciduous or coniferous woodland and traversed by three hedgerows following old fence lines (Fig. 8). There are three buildings near Kirtland-Chardon Road. On the southern border is a small pond drained by a brook which crosses the property in a north-northeasterly direction. Considerable open space remains in the northern field (approximately 375 by 2,000 ft) where the Arboretum's maple collection is located. The southern portion adjacent to Kirtland-Chardon Road is planted with mountain ash (*Sorbus*) and various species of horsechestnut (*Aesculus*), leaving little open space. The remainder of the southern portion consists of an undeveloped and unmowed field approximately 275 by 1,100 ft.

From 1965 through 1975 there were 30 boxes, some of which were gradually relocated away from Kirtland-Chardon Road and the buildings in order to avoid House Sparrow occupancy. In 1976, after studying the history of each box, we removed all but 12, of which 6 were relocated. In 1980 there were 14 boxes.

Pines (P). In 1977 we placed three boxes in the lot on the corner of Kirtland-Chardon and Booth Roads adjacent to the PM area. It is an undeveloped field bounded by coniferous hedgerow, deciduous hedgerow, and woodland except where it meets the two roads. A pair of bluebirds



Fig 8. Paul Martin Farm, Holden Arboretum.

nested in this area each year.

The number of bluebird pairs in PM gradually increased from one in 1965 to three in 1976. After the addition of pines (P) there were three pairs in the combined areas (four in 1978). Usually there were one or two pairs of Tree Swallows in PM.

Goose Pond (GP). Except for the Kirtland-Chardon exposure on the northeast, this area is surrounded by deciduous woodland. It contains five ponds and lakes. There are two dense plantings of mature conifers; one entirely white pine; the other, white pine and spruce (*Picea*). There are many willows (*Salix*). The area available for boxes is divided by a thick hedgerow running north and south. There are six boxes. One pair of bluebirds nested each year of the study. There were also usually one or two pairs of Tree Swallows.

Upper Mather Acres (UMA). This is an unmowed field of coarse grass and weeds (approximately 400 by 2,000 ft) entirely surrounded by mixed or deciduous woodland or thick, dense hedgerow. The northeastern half contains a nursery of small conifers. There were 10 boxes from 1965 through 1974. In 1975, due to vandalism and deterioration, only five remained. Before the 1976 season, we relocated these in an effort to reduce

House Wren interference. Another box was installed before the 1980 nesting season.

With three exceptions (all prior to 1976) there was a pair of bluebirds each year. From 1965 through 1976, presumably due to wren competition, the bluebirds failed in three of nine years. In three additional years, wrens prevented a second nesting by building in the boxes. From 1977 through 1980, one or two broods of bluebirds fledged each year. One pair of Tree Swallows nested in 12 of the last 14 years with only four failures.

Lower Baldwin Farm (LBF). Except where it is bordered by the road, this area is almost entirely surrounded by deciduous or mixed woodland. The higher eastern section contains mature nut trees and the younger nut tree collection. The land slopes south and east to the lower field which contains a mainly deciduous mixed nursery. Except on one steep grassy slope, a patch of deciduous woods separates the two areas.

There were originally 20 boxes in this area. Six of these, south of the extension of Baldwin Road, were relocated in the present area by 1971. From 1968 through 1974, while the number of boxes remained almost constant, many were relocated in an effort to lessen competition from wrens and House Sparrows and attract more bluebirds. Prior to 1976, after studying the history of each box, we reduced the number to nine, of which four were in new locations.

During three of the first four years of the project, only one pair of bluebirds attempted to nest in this area. Only two broods fledged. From 1970 through 1980 there have been two or three pairs every year and 29 broods have fledged. In 1977 a Tree Swallow nesting was interrupted, presumably by a predator. In 1979 and 1980 two pairs of Tree Swallows were successful.

Post-1965 Areas

Upper Baldwin Farm (UBF). This "upper field," (actually lower in elevation than the lower field) is approximately 1,000 by 2,500 ft and is entirely surrounded by mature deciduous and mixed woodland. It contains a mixed deciduous nursery of small trees and shrubs. The grass is not mowed. Four boxes were placed in this area in 1968. Three additional boxes were added in 1969. One box was removed in 1975 after House Sparrows had destroyed bluebird nestlings for two successive years.

During the 13 years this area always had one or two pairs of bluebirds and 26 broods fledged. Since 1969 there was at least one pair of Tree Swallows every year but one. Six Tree Swallow broods fledged.

Norweb (N). This area, added in 1972, is bounded by deciduous woods and by two extensions of its own fields which have not attracted bluebirds. The eastern portion contains a holly planting. The western part is an undeveloped, unmowed field. The number of houses varied from five to eight. Three at the south end near buildings were eliminated or moved due to House Sparrow competition. From 1978 through 1980 there were five boxes.

During its nine years this area always had one pair of bluebirds. Nine broods fledged. There were usually one or two pairs of Tree Swallows. Five Tree Swallow broods fledged.

Methods

Monitoring of Boxes. The original plan in this study was to monitor the contents of the bluebird boxes on a weekly basis, recording the contents and removing House Sparrow nests. Sometimes during the first few years the interval between visits to boxes was as long as two weeks. In 1966 there were no visits after July 16. Since 1978 an effort was made to check the boxes twice a week. Beginning in 1975 we tried to check boxes with nestlings every two days from approximately the fifth to the tenth day. After the twelfth day we used extreme caution in checking. We did not disturb birds which were engaged in house selection or nest building. We disturbed females brooding eggs as little as possible.

Box Placement. During the 16 years of the project we removed some boxes and added others. In 1967 we eliminated two areas (23 boxes) which had attracted only House Sparrows (see Fig. 4, Areas CB and PA). We removed 11 boxes from an island (Area I) in another area for the same reason. The number of boxes in two areas near the Arboretum Reception Center was gradually reduced until none remained in 1979. One of these sites (AB, 17 boxes) was a trail through the woods which lacked sufficient open space to attract bluebirds. The other (AL, 16 boxes) ceased to attract either bluebirds or Tree Swallows after 1975 as it became more heavily used by people and as House Sparrow competition increased. Only one of 28 boxes was left in a remote part of the crabapple area (AC) which was heavily used by people and frequented by wrens and sparrows. Boxes were removed from parts of three areas which attracted only House Sparrows (CA, PM, LBF) and from another area which attracted only wrens (LMA). Roadside boxes, 22 at most in 1969, which were productive for several years, were eliminated gradually due to vandalism, predation and House Sparrow competition. Three new areas with 15 boxes were added, all of which attracted bluebirds (see Fig. 4, UBF, N and P).



Fig. 9. Bluebird box on post with metal guards, winter 1980.

In 1966, we decided that the boxes were placed too close together to meet the territorial needs of bluebirds. Superfluous houses only served to attract wrens and House Sparrows. In an attempt to reduce interference by these two species, we removed some boxes and relocated some, making certain that they were at least 100 ft apart. This was not done during the nesting season. In the winter of 1975 and 1976, after reviewing the history of each box, we reduced the remaining 146 to 100. After this, however, it was still necessary to remove or relocate certain boxes because of new planting or hedgerow growth. In 1980 there were 86 boxes.

Since we found that bluebirds, when their nesting was interrupted, often sought a different site in the same area, we provided several boxes as alternate choices for pairs that might be disturbed (Krieg, 1971:124). We had enough boxes in every area to accommodate such other species as Tree Swallows and Black-capped Chickadees.

We gradually replaced the original fenceposts with metal poles and guards to protect the boxes from predators (Fig. 9).

Banding of Young. Most of the young were banded (Table 3 and Table 14). The banding was done when the birds were no younger than 8 or older than 12 days.

Results

An Analysis of Factors Causing Nest Failures

House Sparrow. The House Sparrow is an aggressive competitor for bluebird nesting boxes (Kibler, 1969:123; Zeleny, 1976:116-119). In the 16-year study evidence indicated that House Sparrows destroyed 3 adult bluebirds, at least 33 young and 55 eggs, and interrupted 89 additional attempts of the bluebird to nest. There is also evidence that they destroyed 9 adult Tree Swallows, 29 young and 24 eggs, and interrupted 12 additional nestings (Table 4). Sometimes we actually witnessed House Sparrows entering boxes and attacking the occupants. In the other cases, we found the House Sparrow nest on top of the bluebird or Tree Swallow nest, often with broken eggs or dead young. Young small enough to be removed were sometimes found on the ground under the box. When they were too large, the House Sparrows usually delayed nest building until we removed them. Two of the bluebird adults were buried under House Sparrow nesting material. The other adult bluebird and the adult Tree Swallows were found in empty boxes early in the nesting season. All of the birds listed as destroyed by House Sparrows were severely pecked on the head.

We always found House Sparrow nests when we first checked the boxes in mid-March. Eggs appeared after the middle of April. Nesting activity peaked in May, continued into June and decreased in July. There were some attempts in August. Most bluebird casualties occurred in May and June. We found House Sparrow nests in boxes less than four feet from the ground and in a box of smaller than average dimensions. In 1980 House Sparrows built in an experimental box with a screentop designed to be "sparrow-proof."

We routinely removed House Sparrow nests from our boxes. More often than not the House Sparrow returned to build again. In 1972, out of 75 cases of nest removal, 9 did not return; 11 came back once; 27 returned twice; 5, three times; 3, four times; 2, five times; 4, six times; and 14, seven times.

In 1970 a bluebird nest was completed on 22 April. On 27 April there was a House Sparrow nest on top of a dead, severely pecked female bluebird in

the bluebird nest. (In this same box four bluebird young were pecked to death by House Sparrows in June of the same year.) We removed this box.

On 10 April 1976, a dead, severely pecked male bluebird was found in an empty box. House Sparrow nests were removed from this box on 23, 27, and 28 April.

On 9 May 1977, I found a House Sparrow nest with three eggs on top of a dead male bluebird which had been pecked severely on the head. This box was removed.

We found evidence that suggests that the House Sparrow's success is not due to the unwillingness of the bluebird to fight or aggressively defend the nesting site or young, but to the fact that the bluebird pairs leave the nest together to seek food and return to the nest almost simultaneously. The eggs and young, therefore, are intermittently left undefended (Goldman, 1975:800).

In 1965 a dead House Sparrow was found at the foot of a box with bluebird young which subsequently fledged. A second brood was destroyed by House Sparrows.

On 18 June 1970, I found a House Sparrow pair at a bluebird house. The four approximately one-week-old bluebird young were alive but seemed weak. All had been pecked on the head and one had been severely pecked on the back. The bluebird pair returned at intervals, chased the House Sparrows away, and fed the young. The sparrows waited until the bluebirds left, at which time the male sparrow perched on the box and the female entered. I chased them away when the female entered and otherwise waited for the bluebirds to return and defend the box.

When the bluebirds seemed to be staying near and defending the box, I left for 20 minutes. When I returned the male sparrow was on the box, the female inside. The young had been pecked more severely and were quiet. The male bluebird returned with food and called softly and repeatedly for some time but did not enter the box when he received no response from the young. When the male House Sparrow returned and sat on the box, the male bluebird did not challenge. The female bluebird returned and both she and the male fluttered around the box calling but did not enter. They made no attempt to chase the male House Sparrow, which finally flew away. The female bluebird perched on the box until the male House Sparrow returned; then she flew to a nearby stake protesting but not fighting. The male House Sparrow entered the box.

During the several hours that I observed them the bluebirds fought aggressively every time they returned to feed the young until the young became too weak to respond to their calls (Hartshorne, 1962:141). At our next visit, three days later, there was a House Sparrow nest on top of the bluebird nest and one dead bluebird young on the ground.

In 1975, a House Sparrow was observed several times leaving a box in which a female bluebird was brooding. This nesting was not interrupted.

In 1976, a dead House Sparrow was removed from a bluebird nest. The nesting was successful.

In 48 cases bluebirds nested successfully in boxes from which House Sparrow nests had been removed (Kibler, 1969:123). In 21 cases Tree Swallows were successful after the removal of House Sparrow nests (Table 4).

House Wren. The House Wren is a formidable competitor for nesting cavities and may destroy eggs and young in boxes which it does not occupy (Zeleny, 1976:120). Since it is a protected native bird we simply included it in our records during the first six years of the project. We attempted to protect the bluebirds by relocating boxes away from hedgerows to discourage wrens (Kibler, 1969:119).

Wrens occupied 49 of 230 boxes in 1965; 95 of 200 in 1970. In six years approximately 900 young fledged. We believe that in this same period wrens destroyed four bluebird young and 40 eggs and interrupted eight other nestings. After 1970 we decided to remove wren nests from boxes which had a bluebird history or were attracting bluebirds. In 1971, wrens occupied or attempted to occupy 92 of 200 boxes; in 1972, 105 of 189. In these two years at least 450 fledged (Tables 6 and 7).

In 1973 and 1974, with the approval of the Arboretum naturalist, we experimented with nest removal and with removal of all but one or two eggs. The majority of wrens kept returning after nest removal but deserted if only one or two eggs remained. In 1973, 135 young fledged. In 1974, only 35 fledged but the destruction of bluebird eggs increased from an average of 9 to 29.

In the 10 years, 1965 through 1974, approximately 1,300 wrens fledged. During this period indications were that wrens destroyed 13 bluebird young and approximately 92 eggs; 5 Tree Swallow young and 14 eggs; and 28 chickadee eggs. When the eggs were pierced and/or the wren built on top of the nest, I attributed the failure to wrens.

Beginning in 1975, we routinely removed wren nests. We occasionally made an exception when bluebirds were nesting nearby. Wrens continued to attempt to occupy about one-fourth of our boxes.

Wrens probably destroyed 21 bluebird eggs in five nests in 1975; 17 eggs in four nests in 1976; 8 eggs in two nests in 1977; 11 in three in 1978; none in 1979; one in one nest and 2 in another in 1980 (Table 7).

The adult bluebird listed as destroyed by House Wrens in Table 7 was a female found in a box in which bluebird nest failure had been followed by two attempts by wrens to nest. Her head was pecked clean of feathers. The wrens subsequently occupied the box.

Predators. Predators of several species destroyed 5 adult bluebirds, 55

young, 110 eggs and 13 Tree Swallow young and 32 eggs (Table 8). Sometimes it was possible to determine that the destruction was caused by a raccoon or a red squirrel, while in other cases the evidence indicated a snake. Often we could not determine the identity of the predator. Greasing the metal fence posts was ineffective. In 1975, we began to replace these posts with round metal poles which could be greased, and in 1977 we began to place rectangular metal guards on the poles (as suggested by Zeleny, 1976:107-109). In 1980 these guards were on all active houses. We have had two cases of predation in boxes so equipped. One box was on a short pole, since replaced. In 1980, one of three eggs disappeared and later two banded young disappeared from a box 52 in. above the ground.

Human Interference. Human interference caused the loss of 9 bluebird young and 49 eggs, and 14 Tree Swallow eggs. Two chickadee nests containing five and six eggs respectively, were removed from boxes in sight of a trail. Three young were found dead at the foot of another box, the door of which was open. We removed these boxes. In 1976 we put Philips screws on boxes in areas open to the public. More recent incidents of human disturbance to the boxes in remote areas made it necessary to put such screws on all boxes (Table 9).

We attempted to keep human interference at a minimum by making the boxes inconspicuous and by removing ones that proved vulnerable.

Unknown Causes of Destruction or Disappearance. We could not always determine the cause of nesting failure. We could not rule out House Sparrows, House Wrens, predators or human beings. Such cases accounted for 19 bluebird young, 57 eggs and 25 nest failures. Three Tree Swallow nests were destroyed by unknown causes.

Parasitism by Cowbirds. On 8 May, 1972, there were two Brown-headed Cowbird (*Molothrus ater*) eggs in a bluebird nest with two eggs. On 16 May a third bluebird egg was in the nest. The two cowbird eggs were removed. Three bluebirds fledged from this nest.

On 15 June, 1971, a young cowbird was found in a Tree Swallow nest with two unhatched eggs (there had been five). In the same year one live cowbird nestling was found in a nest with four dead Tree Swallow young.

Wasps. We removed many wasp nests from boxes. In May 1975, after a bluebird nest with three eggs had been deserted, we found an active wasp nest. In 1975 a Tree Swallow nest with five eggs was deserted after an old wasp nest fell on top of it. In 1978 we began to coat the ceiling and upper walls of the boxes with Vaseline. This reduced but did not eliminate the problem.

Disappearance of Eggs or Young from Nest. Sometimes it was not possible to determine whether eggs or young had disappeared from a nest containing live nestlings. When the nest was infested with fly larvae we as-

sumed that dead young had been removed by the adults. It is unusual for single eggs to disappear from clutches which are otherwise successful (Peakall, 1970:251). When in doubt as to whether an egg or a nestling had disappeared I assumed that a dead nestling had been removed by a parent (Hartshorne, 1962:145-146).

Failure of Eggs to Hatch. In 16 years, eight clutches of bluebird eggs failed to hatch. In the case of one second clutch of two eggs the pair was near the nest on the eighteenth day after completion. Four white eggs, warm on the twelfth day, were cold on the eighteenth. One clutch, the third of the season, was found covered with new nesting material five to eight days after laying was completed. The pair did not return. In two cases one egg was laid and then deserted. In 59 otherwise successful clutches of bluebird eggs, 70 failed to hatch.

Two clutches of Tree Swallow eggs failed to hatch. In 15 partially successful clutches, 38 failed.

Apaulina sialia. Parasitic fly larvae, *Apaulina sialia*, first became a problem in 1968. After two clutches of five young and nine other young were found dead in infested nests we began to dust the nests (with or without eggs but not with young) with rotenone. There were no further casualties in 1968. In 1969 and 1970 the only fatalities from parasites occurred in nests which had not been treated. In 1971 six young disappeared and one was found dead in nests on which rotenone had been used, and in 1972 two clutches of banded young were found dead in infested boxes. One of three was found dead in another nest. Three young fledged from another after fly larvae had been removed by hand. Only one young Tree Swallow fledged from four infested nests in which 18 were dead or missing. Rotenone had been used in all of these nests. In 1973 and 1974, larvae continued to appear in nests treated with rotenone, but 25 young fledged from infested nests after larvae had been removed manually.

In 1975, suspecting that some of the parasitic flies might have developed immunity to rotenone, we decided to remove larvae by hand. Examination of nest material spread out on white paper revealed the presence of many larvae too small to be visible in the box. Since it was impossible to remove them without destroying the nest, our solution was to substitute a man-made nest of dry grass, as described by Johnson (1932:29) and Mason (1944:232).

From the larvae and pupae which we collected, Dr. Sonja Teraguchi (entomologist at the Cleveland Museum of Natural History) hatched adult *Apaulina sialia* and the hyper-parasite *Mormoniella*. She advised us to remove infested nests and place them at the foot of the boxes in wire mesh bags which would confine adult *Apaulina sialia* but permit the smaller *Mormoniella* to escape. We followed this procedure in most cases. We sub-

stituted artificial nests of dry grass which the bluebirds never failed to accept.

From 1975 through 1979, 60 bluebird and 9 Tree Swallow young died in infested nests, most of which probably had not been checked soon or thoroughly enough. During the same period 152 bluebird and 61 Tree Swallow young fledged from nests that had been substituted for infested ones. In 1980, although larvae were present in the nests of 18 broods, there were no nest failures. Four bluebird young were found dead or disappeared from four nests in which larvae were present. Two Tree Swallows were found dead and one disappeared from two such nests.

Apaulina sialia appeared from late May through August. They were present in every area. In some cases they were present in the first nesting but not the second in the same box; in other cases the reverse was true. In 1979, in at least 10 cases larvae were present—even abundant—one to three days after the box had been cleaned. They were found after all or part of the young had fledged in boxes that had been cleaned on the tenth to twelfth days. During six seasons (1975-1980) larvae were found in the nests of 103 of 155 broods in which young survived to the age of one week (see Table 10).

Other Parasites. On 10 July 1975, two bluebirds, 1 or 2 days old, were dead in the nest. Dr. Teraguchi found them covered with microscopic larvae. (Of 4 eggs, 2 had disappeared, one at a time.)

In 1973 a Tree Swallow nest had six eggs due to hatch on 20 June. On 25 June there were four live young and one dead. On 2 July there were only two young. The nest was infested with tiny flies which a volunteer removed. On 6 July there were a few flies which were removed. The young were banded on 10 July, when they were approximately 20 days old. Two days later one of the young was seen leaving the nest. Both fledged.

Young Dead in Nest—Cause Unknown. In June of 1976 a volunteer described one of four Tree Swallow young, 19 or 20 days old, as "sick." There had not been and were at no time any visible parasites in the box. Two days later there were three dead young.

On 9 June, 1977 I banded four bluebirds approximately eight days old. They were active and seemed healthy. No larvae were present. The adults fed them as soon as I left. Two days later they were dead. I took these young to Dr. Aaron Leash, a local veterinarian, who found them to be well nourished. He dissected one and could find no parasites or abnormalities.

In a nearby area on 8 June, two young approximately two days old were found in a nest which had had six eggs. One tiny nestling was dead on the ground at the foot of the box. On the 11th, I found the two young ailing, one on its back and one on its side. The adults were in a nearby tree. After consulting the Arboretum naturalist, I gave each nestling two drops of vit-

amins which seemed to revive them. The parents fed them before I left. We administered vitamins again on 13 and 15 June. The young fledged at approximately 17 days.

In a nearby area three Tree Swallow young, hatched on 8 June, seemed normal on 11 and 13 June but were dead on the 18th. No larvae were found.

These three boxes were near ornamental trees and shrubs which had been sprayed. After that date, the Arboretum kept me informed of any necessary spraying, which was always selective.

Weather. Kibler states, "That inclement weather can be a significant factor in bluebird mortality is borne out by the result of my first nesting period in 1968 in which 76% of 51 nestlings died in the nest" (1969:125).

On four occasions in the course of our study adverse weather conditions appeared to be the cause of young mortality and/or failure of eggs to hatch.

In 1973, from 4 to 6 May, the temperatures of the Chardon, Ohio, weather bureau were recorded as follows:

	<i>Maximum</i>	<i>Minimum</i>
4 May	48	32
5 May	42	29
6 May	56	30

There were six bluebird nests in five of which dead young were discovered or from which young were missing:

- 1) On 6 May, four young, hatched approximately 20 April, were dead.
- 2) On 7 May, four young, hatched on 1 May, were dead.
- 3) On 9 May, a nest which had had four young approximately four days old on 3 May, was empty.
- 4) On 9 May, one of three young, newly hatched on 1 May, was missing.
- 5) One nest had four eggs on 29 April. On 5 and 11 May the incubating female did not leave. On 20 May the female was dead on the nest with two dead young several days old.
- 6) On 21 April, a female was incubating five eggs. On 29 April there were four young and one egg. Four young were banded on 8 May and fledged.

No fly larvae were found in these boxes.

Of seven nests with eggs, one clutch of five and one of two failed to

hatch. In three clutches, one of five, one of three, and one of four failed to hatch.

On 27 April, 1976 daytime temperatures were in the low 30s; there was a ground cover of snow on 3 May, and the temperature was in the low 30s in the daytime of 4 May.

During this period there were six nests with young:

- 1) One brood of four hatched approximately 25 April had food in their stomachs on 27 April. They were alive on 4 May, dead on 8 May.
- 2) One brood of four hatched approximately 2 May were alive on 6 May, dead on 8 May.
- 3) One brood of five alive and approximately one week old on 5 May were dead on 10 May.
- 4) Two young alive and approximately three days old on 5 May were dead on 10 May.
- 5) One nest which contained three eggs on 14 and 28 April contained one egg and one young on 5 May. On 9 May there was only one egg.
- 6) One nest which had four eggs due to hatch on 3 May had three young and one egg on 8 May. The three young fledged in spite of fly larvae infestation after a new nest was substituted.

No fly larvae were found in the first five boxes.

Of six clutches of eggs, two failed to hatch.

On 8 May, 1977, a cold front moved across Lake Erie with wind gusts in excess of 70 mph. The temperatures ($^{\circ}$ F) in Chardon for that day and the ensuing four were as follows:

	<i>Maximum</i>	<i>Minimum</i>
8 May	56	27
9 May	65	31 (45 $^{\circ}$ during day at Arboretum)
10 May	46	28
11 May	55	27
12 May	66	34

During this period there were five nests with young:

- 1) In a box at the highest elevation in the area, only one of five young survived. These young hatched between 3 and 7 May. No fly larvae were found.

- 2) One of a brood of five hatched between 5 and 7 May was alive on 22 May but dead in the box after the others fledged. Fly larvae were present.
- 3) Two young hatched on 8 May and fledged.
- 4) One of five young hatched between 2 and 7 May disappeared on or before 8 May. Another disappeared between 8 and 13 May. On 15 May the remaining three were dead. Fly larvae were removed on 13 May.
- 5) In one box were five eggs due to hatch on 5 May. There were only four young on 8 May. One of these disappeared by 23 May, when fly larvae were found. The others fledged.

There were six nests with eggs:

- 1) In one clutch completed on 3 May, four of five hatched.
- 2) One clutch of four was completed on 8 May. The female was incubating on 15 and 21 May. On 23 May the eggs were gone.
- 3) One nest contained five eggs on 23 April and 3 May. On 10 May, a Tree Swallow had built on top. We do not know if the eggs failed to hatch or if the Tree Swallow drove the bluebirds away.
- 4) A clutch of five eggs present on 24 April and 9 May had hatched by 16 May (probably on 9 or 10 May).
- 5) Of four eggs present on 9 May, one disappeared and three hatched.
- 6) On 9 May a female was brooding five eggs due to hatch 11 May. On 16 May there were two unhatched eggs and one dead nestling.

In 1979 the maximum and minimum temperatures ($^{\circ}$ F) and the precipitation (inches of rain) at Chardon were as follows from 24 through 27 May.

	<i>Maximum</i>	<i>Minimum</i>	<i>Precipitation</i>
24 May	73	35	.00
25 May	53	36	2.00
26 May	52	38	.70
27 May	51	35	.73

In five boxes, 24 healthy young free of fly larvae and banded or ready to band were found dead on 26 and 27 May. They were from one to two weeks old on 24 May. Four in another brood which hatched on 6 May and had not developed normally, although free of fly larvae, were also dead on 26

May. In one clutch of four dead on 26 May, fly larvae were present. In two cases in which three of five and four of five approximately two weeks old were found dead, fly larvae were present. The three young which fledged from these two nests were the only ones to survive this cold spell. Three nests with eggs were not affected; all hatched.

The four Tree Swallow nests which contained eggs were deserted. In every case the pairs made a new start in the same box.

(On 26 May there was no activity in the barn where Barn Swallows (*Hirundo rustica*) were nesting except for two brooding adults. On 27 and 28 May, seven adults were dead on the floor. The nests containing eggs were deserted.)

White Eggs

From 1973 through 1980 we found 44 white or extremely pale blue eggs in 10 clutches, six of which were at least partially successful. Of the 18 banded young, none was recaptured. Two of the females producing white eggs had hatched from blue eggs.

Clutch Size

Clutch size varied from 3.9 in 1968 to 4.66 in 1965 and 1980. The average was 4.22. I used only completed clutches to make this calculation (Table 11).

Breeding Season

The breeding season in terms of clutch completion extended from the first week in April to mid-August. The 16-year average shows a peak in late April and early May and a lower peak from 9 to 28 June (Table 12).

Interval Between Broods

In computing the interval between fledging or nesting interruption and the laying of the first egg of the next clutch I have used only pairs which have nested a second or third time in the same house. If I did not know the exact dates I used 14 days as the incubation period and 17 days as the age of

fledging (Clapp, 1974:15-19; Thomas, 1946:156-158). From fledging to laying of first egg in 22 broods of one to three young the average interval was 20 days. The range was from 42 days to 8 days. In 60 broods of four or five the average interval was 24 days. The range was 42 to 9 days.

In five nest failures involving eggs the intervals were 65, 54, 32, 21, and 2 or 3 days with an average of 25. In 13 nest failures involving young the average interval was 19.4 days with a range of 45 to 8 days.

Banding Records

Most of our bluebird young were banded (Table 3). We were able to pick up 10 brooding females and record their band numbers. Nine of these had been banded as nestlings. Four were 6, 5, 4, and 3 years old respectively. Two were 2 years old; three only 1 year old. One was found in two different boxes, the second of which was the one from which she had fledged. One, banded as a brooding female, was brooding in the same box the following year.

We have a five-year record on our most productive box. The female in this box in 1973 and 1974 had been banded as a nestling in 1969. The female in the box in 1975 had been banded as a nestling in 1972 in another area. In 1976, the female in this box was unbanded. I banded her and was able to recapture the same female in the same box in 1977.

On 30 June 1980, I caught a small flock of bluebirds in a net. The adult pair was unbanded. Three juveniles had fledged between 9 and 12 May from a nearby box; two had fledged from another box on 4 June.

Tree Swallows

Population. In 1966, only one pair of Tree Swallows nested in one of our boxes. Since then there has been a gradual increase. The average number of pairs for 15 years (1966-1980) is nine. In 1980, there were 13 pairs. They laid 747 eggs, of which 567 hatched. The number of young fledged fluctuated from four in 1972 to 51 in 1980, with the total at 396 (Table 14 and Fig. 3) and the average clutch size, 5.03 (Table 15).

The breeding season computed on the basis of clutch completion extended from 10 May to 22 June. Over 73% of the clutches were completed between 20 May and 8 June (Table 16).

In seven cases a Tree Swallow female laid a second clutch in the same

box after the first was interrupted. One female swallow laid eight eggs between 10 May and 1 June. On 8 June there were eight eggs. On 19 June the box contained one intact egg, a broken egg, and a newly hatched dead young. In one box, four of five eggs hatched after which three of the young disappeared. Following this, two more eggs were laid, but failed to hatch. The remaining young fledged.

There were two cases of second broods of Tree Swallows, both in 1980. One brood of six, which hatched on 3 June, was dead on 11 June (last seen alive on 9 June). On 19 June, presumably the same pair of adults was building in a nearby box. On 22 June, there were four eggs; three young fledged. In the other instance, five of seven young fledged after 14 June. On 22 June a new nest with one egg was found on top of the old. Of four eggs laid, one hatched. The bander discovered two dead young from the first clutch under the new nest.

Tree Swallow broods often include one nestling smaller than the others. Occasionally there are two. These birds often fail to fledge, particularly if fly parasites are present. In our study, excluding cases of total or partial nest failure due to other causes: of two broods of seven all fledged in one, two were found dead in the other; of 20 broods of six all fledged in 11, one disappeared from or was found dead in nine; of 38 broods of five all fledged in 23, one disappeared or was found dead in 11, and two disappeared or were found dead in four.

Banding Records. Tree Swallows were not present in every area each year (Table 2). I banded 37 brooding adults in 1975-1980. During the same period, 200 young were banded. From 1966 to 1974, approximately 100 were banded (Table 14). We have had only three recoveries of these banded birds. Two adults banded in 1975 were brooding in different areas in 1976. One adult found dead in a box in 1974 had been banded in a box one mile away in 1973. Although certain boxes appeared to be preferred, we have no evidence that the same swallows return to the same nest sites year after year.

Bluebird-Tree Swallow Competition

Tree Swallows seldom interfered with the bluebirds. The instances of competition were too rare to be significant. The two species appear to share the same enemies and benefit from the same measures to protect them from House Sparrows, House Wrens, predators, human interference and parasitic fly larvae.

Productiveness of Boxes—Bluebird and Tree Swallow

One box, occupied by bluebirds for 12 consecutive years, produced 45 young; another occupied 10 consecutive years, 54 young. From each of three boxes 26 young fledged. Young fledged from all but one of these boxes in 1980. Of our 12 most successful boxes, 11 were still in use in 1980. The following table shows years of bluebird occupancy.

<i>Number of Boxes</i>	<i>Number of Years</i>
2	12
1	11
1	10
2	9
4	8
5	7
18	4
19	3
20	2

Of 82 boxes occupied more than once, 54 were still in use in 1980. The other boxes were removed either because they had ceased to attract bluebirds or because of repeated bluebird nesting failures. Of 86 boxes present in 1980, bluebirds had occupied or attempted to occupy 65; Tree Swallows, 39. Both species had occupied 28.

The following table shows occupancy of boxes by Tree Swallows:

<i>Number of Boxes</i>	<i>Number of Years</i>
4	6
1	5
3	4
4	3
18	2

No box has been occupied by Tree Swallows for more than three consecutive years. Of the 12 boxes occupied for three or more years, 11 were still in use in 1980.

Natural Cavities. On two occasions, we observed bluebirds nesting in natural cavities. In 1966 a pair was seen on 26 April, 5 May, and 9 May entering and leaving a hole in a dead stump projecting from the top of an old white oak (*Quercus alba*) in the center of a small bog (Fig. 4, HP). On 17 May, House Wrens had occupied the cavity. During June 1980 a pair nested in a hole in a sassafras approximately 20 ft above the ground (Fig. 4, CL).

Black-capped Chickadees

Chickadees attempted 23 nestings from 1967 through 1980. There have been 11 broods. Of 108 eggs laid, 58 hatched and 55 young fledged. House Wrens destroyed 28 eggs and interrupted two other nesting attempts. Human interference caused the loss of three young and 11 eggs. Bees interrupted one nesting (Table 17).

Bewick Wrens

In July 1969 a pair of Bewick Wrens attempted to nest in a box in area CA (Fig. 4). They completed a nest (more grass than twigs) on the 21st. Ten days later, House Wrens were in the box.

Discussion

During the 16 years of the project, the minimum number of nesting pairs increased from 8 in 1965 to 18 in 1980 (Table 3). From 1972 through 1976, the number fluctuated from 18 to 23. In 1972, when there were 19 pairs, 3 were in roadside houses. In 1973, 3 of the 22 pairs were in roadside houses, one in an area which subsequently became unsuitable for bluebird boxes. In 1974, 3 of the 23 pairs were in roadside boxes, 2 in areas which became unsuitable. In 1976, 2 of the 21 pairs were in roadside houses. After 1976, we removed the remaining roadside houses because of human interference and House Sparrow competition.

The average clutch size during the 16 years was 4.22. Peakall (1970:249) found an average of 4.48 for Ohio based on 631 nest cards (97 prior to 1964;

the remainder from 1964 to 1969). Since he used records from various parts of Ohio and covered a different period, some differences could be expected (Table 11).

Following Peakall's procedure, I have based my computation of seasonal activity upon clutch completion. Table 12 shows the number of clutches completed in each 10-day period of each season. It also shows the percentage of the total number of clutches for 16 years completed during each 10-day period. In Table 13 my figures are compared with those of Peakall. Since his study covers a larger part of Ohio and ends in 1969, it is difficult to compare his data with the present study (Peakall, 1970:245-251).

The number of young fledged fluctuated between a low of 31 in 1967 to a high of 110 in 1980. The 1966 figure is based on incomplete data. In spite of fluctuations, the fledging trend has been upward (Table 3 and Fig. 2). Nest failures have been reduced by measures taken to deal with specific problems.

House Sparrows. Regular removal of House Sparrow nests made more boxes available for nesting bluebirds and Tree Swallows. Both species had successful nestings in boxes from which House Sparrow nests were removed (Table 4). We eliminated House Sparrow productivity in our boxes. The number of boxes in which nesting attempts by House Sparrows occurred decreased (Table 5) as we removed or relocated those which attracted them, often near buildings (Zeleny, 1976:74). We were not able to keep these aggressive birds from attempting to occupy some of our boxes or to eliminate them as occasional causes of bluebird or Tree Swallow nesting failure (Table 4).

House Wrens. The House Wren, a native bird and a natural competitor for bluebird nest sites, posed a more complex problem than the House Sparrow. During the first 10 years of the project, approximately 1,300 wren young fledged from our boxes. After 1975, when we began to remove wren nests routinely, no more young fledged. We believe that wrens will not tolerate competition for available insects within 50 to 100 ft of their nesting cavity. They frequently pierce the eggs in boxes near their own even if they do not subsequently occupy these boxes. To reduce such interference we placed our boxes more than 100 feet apart. Because wrens prefer nest sites near shrubbery (Kibler, 1969:119), we placed our boxes as far into the open as was possible to do and still provide a safe landing for the bluebird young on their first flight (Zeleny, 1976:74). As we removed boxes attractive to wrens, the number which they attempted to occupy decreased (Table 6). We were able to reduce but not eliminate wren interference with nesting bluebirds (Table 7).

Predation. Failure due to predation seemed to increase with the increase in the bluebird population (Table 8). Regular monitoring of the boxes may have been a factor. From 1977 on, rectangular sheet metal guards folded around the poles seemed to keep most would-be predators out of the boxes. It is probably not possible to eliminate predation by raccoons.

Human Interference (Table 9). Part of the losses due to human interference can be described as theft or vandalism. Some were due to curiosity and carelessness. We found that boxes fastened with Philips screws were protected from interference by human beings who wished to remove or merely look at their contents. Occasionally an entire box was damaged or removed. We kept this kind of destruction at a minimum by removing vulnerable houses and by keeping our boxes as inconspicuous as possible. With the exception of one dark green box, the boxes were unpainted. The metal guards were painted dark brown.

Apaulina sialia. These larvae were present in two-thirds of our broods of bluebirds and 154 young died in infested nests (Table 10). Rotenone, effective in 1968, 1969, and 1970, lost its effectiveness from 1972 to 1974. Beginning in 1975, we removed larvae manually, which necessitated removing the infested nest and substituting one of grass made to simulate the original nest as far as possible. We found larvae as early as the fifth day, when we felt that the young could be handled safely. We found it necessary to change the nest one or two more times at two-day intervals. When this procedure was followed, there were few if any fatalities from these parasites. The infested nest was placed in a mesh bag at the foot of the box. Adult *Apaulina sialia* flies could not escape. The smaller *Mormoniella* which parasitizes the *Apaulina sialia* pupae could leave or enter the bag. We do not know if larvae pupated or if adult *Apaulina sialia* emerged within these bags. We have no proof of the presence of *Mormoniella* in the bags. We followed this procedure in an effort to permit natural control of *Apaulina sialia* by *Mormoniella*.

Removal of the young bluebirds and returning them to a substitute nest did not disrupt the nesting process. One removal could be combined with banding. The fly larvae, if unchecked, caused so many fatalities in our area that a routine nest change on the fifth or sixth day seemed to us to be a wise precaution.

Weather. It appeared that in certain years adverse weather conditions in northeast Ohio caused nest failures. This occurred during four years of our study. Fortunately, most bluebird pairs when interrupted go on to a second or even a third nesting. Eight pairs attempted a second nesting in the same box, and five pairs were successful. One pair which lost four of five young raised two more broods in the same box. Often bluebirds seek a dif-

ferent box near the one in which they have had a nest failure. We believe that in eight cases of nest failure during cold weather the pairs had second nestings in nearby boxes. One pair apparently moved to a nearby box and, after an interruption by House Sparrows, moved to the original box and raised a brood. One pair probably had two successful nestings in a nearby box.

Since we did not dissect any of the young that died during periods of cold weather, we do not know if starvation due to a temporary dearth of available insects was a factor. Of 23 survivors, 14 were less than a week old, 5 approximately one week old, and 4 approximately two weeks old. It may be that birds young enough to be brooded have a better chance of survival. The 82 young that died varied in age from one day to two weeks.

Because we cannot eliminate all the causes of bluebird nest failure, we feel that in the future the number of fledglings will continue to fluctuate. It seems clear that humans can help the bluebird population to maintain itself, if not to increase.

If every portion of our study area in use in 1980 were occupied according to its demonstrated capacity, we might expect to have 21 nesting pairs. Bluebirds nest on some properties adjacent to the Arboretum. In two instances, brooding females banded as young at the Arboretum were captured on such properties. Other bluebirds nesting in the vicinity have been observed to be banded. It seems reasonable to expect that any population increase will take the form of territorial expansion rather than increased concentration on Arboretum property.

Summary

During 16 years (1965-1980) a study was made of a volunteer effort to increase the population of the Eastern Bluebird, *Sialia sialis*, at the Holden Arboretum in Lake County, Ohio. In 1965 there were 230 boxes in 14 areas. Eight boxes were occupied by bluebirds, 49 by House Wrens (*Troglodytes aedon*), and 134 by House Sparrows (*Passer domesticus*).

During the study, five areas with 64 boxes were eliminated and three areas with 16 boxes were added. The total number of boxes was gradually reduced to 86. In 1980 bluebirds occupied 22; Tree Swallows (*Iridoprocne bicolor*) 15; and Black-capped Chickadees (*Parus atricapillus*) 2. House Sparrows attempted to occupy 15; House Wrens, 22.

The minimum number of nesting bluebird pairs increased from 8 to 18 or 19 (Table 1). The number of young which fledged fluctuated from 10 in

1966 to 110 in 1980 (Table 3 and Fig. 2).

The following measures were taken to deal with specific causes of bluebird nest failure:

House Sparrows. Removal of boxes that attracted only sparrows reduced the number of their nesting attempts. Relocation of others discouraged but did not stop sparrow competition. Regular removal of sparrow nests eliminated their reproduction in the boxes and made more boxes available for bluebirds.

House Wrens. Removal of boxes occupied only by wrens and relocation of others as far into the open as possible reduced the number of attempts by this species to nest in bluebird boxes. From 1975 on, wren nests were removed from the boxes. These measures reduced but did not eliminate bluebird nest failures due to wrens.

Predators. Rectangular metal guards folded around the posts were found to be effective against most would-be predators.

Human Interference. The use of Philips screws in the doors of the boxes prevented nest failures caused by humans.

Apaulina Sialia. Larvae of this species were present in two-thirds of the boxes in which bluebird young survived to the age of one week, and 154 young died in infested nests. Rotenone, effective at first, became useless as the flies apparently developed immunity to it. We found that nest failures caused by these parasites could be prevented by removing nests when the young were five days old and substituting nests of grass made to simulate the original. This procedure did not interfere with the nesting process.

The following tables show what we believe to be causes of failure of eggs to hatch and of young to fledge in order of numerical significance.

<i>Causes of Failure</i>	Bluebird Eggs	<i>Number of Eggs</i>
House Wrens		152
Predators		110
House Sparrows		55-57
Human Interference		49
Clutch Failed to Hatch or Abandoned		36
Weather		21
Wasps		3

Bluebird Young

<i>Causes of Failure</i>	<i>Number of Young</i>
<i>Apaulina sialia</i>	154
Weather	82
Predators	55
House Sparrows	33-35
House Wrens	13
Human Interference	9

Tree Swallow Eggs

<i>Causes of Failure</i>	<i>Number of Eggs</i>
Predators	32
House Wrens	31
House Sparrows	24
Human Interference	14
Cowbirds	5
Wasps	5
Bluebirds	2
Weather	2

Tree Swallow Young

<i>Causes of Failure</i>	<i>Number of Young</i>
<i>Apaulina sialia</i>	46
House Sparrows	29
Weather	21
Predators	13
House Wrens	7
Cowbirds	4

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TABLE I
Eastern Bluebirds: Number of Nesting Pairs, by Area and Year

Areas	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80
T	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
C	3	3	3	3	4	2	4	4	3	3	4	4	3	3	4	3
HP							1	1	1	1	1	1	1	1	1	1
CA				1	1	1	2	2	2	2	2	3	2	2	2	2
BA			1	1				1	1	1	1	1	1	1	1	1
N								1	1	1	1	1	1	1	1	1
GP	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1
PM	1	2	1	1	2	3	2	2	3	3	3	3	2	3	2	3
Pines													1	1	1	1
UMA	1	1	1	1	1			1	1	1		1	1	1	1	1
LBF		1	1	1	2	3	3	2	2	3	2	2	2	2	2	2
UBF				1	1	1	1	2	2	2	1	1	1	1	1	2
AB & AL			1	2	1	1		1	1	1						
LMA			1							1	1		1			
Roadside																
TOTAL	8	11	11	12	17	16	17	19	22	23	18	21	18	16	19	19*

*18 if pair at T moved to C

TABLE 2
Tree Swallows: Number of Nesting Pairs, by Area and Year

Areas	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80
T					1											
C		1	1	2	2	4	2	1	4	4	3	1		1	1	1
CA		1	1	1	1	1	1	1	1	1	2	3	2	1	2	2
BA							1					1			1	1
N									1	1	2					2
GP				1	1		2	2	1	2	2	3	4	2	1	1
PM				1		2	1	1	1	1	2	1	1		2	2
UMA			1		1		1	2	1	1	1	1	2	1	1	1
LBF													1		2	2
UBF					1	1	2		1	1	1	1	1	2	1	1
AB & AL			1	1	1	1	2	2	1	2						
LMA														1		
TOTAL	0	1	4	6	8	9	12	9	10	13	13	12	11	8	11	13

TABLE 3
Eastern Bluebird Nesting Data

	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80
Minimum																
Number of Nesting Pairs	8	11	11	12	17	16	17	19	22	23	18	21	18	16	19	18 or 19
Number of Broods	12	15	18	19	18	20	24	22	36	26	29	28	30	22	32	28
Number of Eggs Laid	57	50	68	74	108	98+	146	140	171	183	166	181	143	112	163	144
Number of Eggs Hatched	52	19	40	67	75	79	93	94	130	103	98	107	118	97	135	121-23
Percent of Eggs Hatched	91	37	58	90	70	80	64	67	76	56	59	59	82	85	84	84
Number of Young Fledged	45	10	31	44	68	59	76	70	86	59	61	59	78	86	73	110
Percent of Young Fledged from Hatched Eggs	86	52	77	69	90	75	82	82	70	59	61	55	66	88	54	90
Number of Young Banded	36	10	20	37	69	58	72	68	92	56	61	71	81	86	88	116
Total Number of Eggs Laid:	2,004															
Total Number of Eggs Hatched:	1,428-30															
Total Number of Young Fledged:	1,015															

TABLE 4
Effects of House Sparrows on Eastern Bluebird Box Nesters

Year	Destruction of Eastern Bluebirds			Successful Bluebird Nestings after Removal of House Sparrow Nest			Destruction of Tree Swallows			Successful Tree Swallow Nestings after Removal of House Sparrow Nest	
	Adults	Young	Eggs	Other Nest Interruptions	Sparrow Nest	of House Sparrow Nest	Adults	Young	Eggs	Other Nest Interruptions	of House Sparrow Nest
1965		7	5	47		2					
1966			9	6		2					1
1967				2		1		5			1
1968				1		5					1
1969											1
1970	1	4	3	3		4					3
1971			12	4		4					1
1972			10	2		1				3	4
1973				8		8		5		1	1
1974		12	1	2		7	1			1	4
1975		5	2	7		3	2	8	12		
1976	1		6	3		3	2	3	5	2	3
1977	1	3		2		3	2	8	2		1
1978				6		4	1				2
1979			4			1	1				
1980		2-4	3-5								
TOTAL	3	33-35	55-57	89		48	9	29	24	12	21

TABLE 5
House Sparrow Occupancy of Eastern Bluebird Boxes

<i>Year</i>	<i>Total Boxes</i>	<i>Number of Boxes House Sparrows Attempted to Occupy</i>
1965	230	134
1966	236	179
1967	228	150
1968	204	112
1969	201	76
1970	200	91
1971	200	100
1972	189	99
1973	178	72
1974	171	77
1975	146	69
1976	100	65
1977	97	50
1978	89	40
1979	84	26
1980	86	15

TABLE 6
House Wren Occupancy of Eastern Bluebird Boxes

<i>Year</i>	<i>Occupied or Attempted to Occupy</i>	<i>Earliest and Latest Dates Found in Boxes</i>	<i>Period during which Bluebird Eggs Were Destroyed</i>
1965	49 of 230	No Record	
1966	53 of 236	8 May, 16 July	May and June
1967	92 of 228	5 May, 18 Aug.	May
1968	91 of 204	29 Apr., 23 Aug.	May through July
1969	89 of 201	26 Apr., 27 Aug.	April through July
1970	95 of 200	29 Apr., 12 Aug.	May and June
1971	92 of 200	1 May, 24 Aug.	May through July
1972	105 of 189	21 Apr., 17 Aug.	June and July
1973	77 of 178	29 Apr., 24 Aug.	April through June
1974	93 of 171	29 Apr., 18 Aug.	May through July
1975	72 of 146	2 May, 2 Sept.	April through August
1976	43 of 100	10 May, 18 Aug.	May through July
1977	29 of 97	16 May, 18 July	May
1978	21 of 89	16 May, 13 Aug.	June
1979	18 of 84	2 May, 13 Aug.	None
1980	22 of 86	3 May, 2 Aug.	June and July

TABLE 7
Effects of House Wrens on Other Eastern Bluebird Box Nesters

Year	Bluebirds Destroyed	Bluebird Eggs		Other Eastern Bluebird Nest Interruptions		Tree Swallow Young		Tree Swallow Eggs		Tree Swallow Nest Interruptions		Chickadee Eggs Destroyed		Other Chickadee Nest Interruptions	
		Destroyed	Destroyed	Destroyed	Interruptions	Destroyed	Destroyed	Destroyed	Destroyed	Interruptions	Destroyed	Destroyed	Interruptions		
1965				1											
1966		13		1											
1967		4		1								8			
1968	4	4		3								10		1	
1969		8		1											
1970		11		1											
1971		6						4							
1972		9		2				4							
1973	5	8		1			5								
1974	4	29		2				6							
1975		21							11						
1976	1 adult	17		1											
1977		8		2			2		6						
1978		11													
1979				1											
1980		3													
TOTAL	1 adult 13 young	152		17		7		31				28		2	

TABLE 8

Numerical Summary of Predation on Eastern Bluebirds and Tree Swallows

<i>Year</i>	<i>Eastern Bluebirds</i>			<i>Tree Swallows</i>	
	<i>Adults</i>	<i>Young</i>	<i>Eggs</i>	<i>Young</i>	<i>Eggs</i>
1965					
1966					
1967		4			
1968					
1969			4		
1970		4	?		
1971	2	10	9		
1972		4	17		
1973	1	3	9		
1974			18		3
1975	1	17	23	5	13
1976	1	8	16	4	3
1977			4		9
1978		3		4	4
1979			9		
1980		2	1		
TOTAL	5	55	110+	13	32

TABLE 9

Detrimental Effect of Human Interference on Nesting Success

<i>Year</i>	<i>Bluebird</i>		<i>Tree Swallow</i>		<i>Chickadee</i>	
	<i>Young</i>	<i>Eggs</i>	<i>Young</i>	<i>Eggs</i>	<i>Young</i>	<i>Eggs</i>
1969		6				
1970						
1971		12				
1972		3				
1973		2				11
1974		15			3	
1975	5	2				
1976		4		1		
1977	2					
1978				5		
1979	2					
1980		5		8		
TOTAL	9	49	0	14	3	11

TABLE 10
Incidence of *Apaulina sialia* in Eastern Bluebird Nests

<i>Year</i>	<i>Number of Broods in Which Young Survived One Week</i>	<i>Number Infested With Apaulina sialia</i>
1975	27	23
1976	18	12
1977	30	23
1978	21	9
1979	32	18
1980	27	18
TOTAL	155	103

TABLE 11
Computation of Eastern Bluebird Clutch Size

<i>Year</i>	<i>Completed Clutches</i>	<i>Eggs Laid</i>	<i>Average Size</i>
1965	12	56	4.66
1966	11	44	4.00
1967	17	68	4.00
1968	19	74	3.90
1969	25	105	4.20
1970	23	92	4.00
1971	34	142	4.17
1972	30	131	4.36
1973	41	164	4.00
1974	41	177	4.31
1975	41	161	3.92
1976	42	176	4.19
1977	34	143	4.20
1978	25	109	4.36
1979	35	160	4.57
1980	30	140	4.66

Average clutch size for the 16 years: 4.22.

TABLE 12
 Dates of Eastern Bluebird Breeding Season Based on Clutch Completion

Year	3/11	3/21	3/31	4/10	4/20	4/30	5/10	5/20	5/30	6/9	6/19	6/29	7/9	7/19	7/29	8/8
	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to
	3/20	3/30	4/9	4/19	4/29	5/9	5/19	5/29	6/8	6/18	6/28	7/8	7/18	7/28	8/7	8/17
1965				1	2	2			5	2						
1966				2	1	1	1	3	3	4						
1967				2	2	2	1	1	1	6	2		1			
1968				1	3	1	3			5	4		2			
1969				2	5	4	2	1	2	1	7	2		1		
1970				2	1	3	3	4	4	2	4	3	2	1	1	
1971				3	7	3	3	1	1	11	3	1	1	5		
1972					5	9	2	2		4	6	5	1	2		
1973			2	4	6	5	4	3	4	3	4	4	2	2	2	
1974					12	3	3	5	5	1	3	6	5		1	
1975	1			2	2	9	2	3	5	4	5	3	4	1		2
1976			1	7	6		4	8	2	5	2	2	3	2		
1977				1	7	4	1	1	4	3	3	3		2	4	
1978				1	2	6	1	1	4		6	2		1	2	
1979					10	5	3	2	4	4	2	2	1	3		
1980			1	2	7	4	1	2	3	2	7	2		1		
TOTAL	1	4	4	28	78	58	34	37	47	57	58	35	22	21	10	2

TABLE 13
Breeding Season of Eastern Bluebird:
Percentage of Clutches Completed in Each 10-Day Period

<i>Dates</i>	<i>Ohio</i> <i>(Peakall, 1970:246)</i>	<i>Holden Arboretum</i> <i>1965-80</i>
11 Mar.-20 Mar.		0.20
21 Mar.-30 Mar.	0.17	0.00
31 Mar.-9 Apr.	0.33	0.81
10 Apr.-19 Apr.	9.52	5.69
20 Apr.-29 Apr.	18.03	15.85
30 Apr.-9 May	10.52	11.79
10 May-19 May	7.35	6.91
20 May-29 May	7.68	7.52
30 May-8 June	11.52	9.55
9 June-18 June	12.02	11.58
19 June-28 June	10.18	11.78
29 June-8 July	6.18	7.11
9 July-18 July	3.34	4.47
19 July-28 July	2.34	4.26
29 July-7 Aug.	0.33	2.03
8 Aug.-17 Aug.		0.406

TABLE 14
Tree Swallow Nesting Data

	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80
Minimum															
Number of Nesting Pairs	1	4	6	8	9	12	9	10	13	13	12	11	8	11	13
Number of Broods	1	4	5	8	8	10	8	9	10	9	9	11	6	9	15
Number of Eggs Laid	5	23	25	36	44	63	59	56	63	77	54	71	41	47	83
Number of Eggs Hatched	5	22	14	33	36	48	40	47	46	44	43	54	29	39	67
Percent of Eggs Hatched	100	95	56	91	81	76	67	84	73	57	79	76	70	83	80
Number of Young Fledged	5	16	11	32	24	43	4	33	36	32	28	33	24	24	51
Percent of Young Fledged from Hatched Eggs	100	73	79	97	67	89	10	70	78	73	65	61	82	61	76
Number of Young Banded	5	15	---	No Record---	30	9	34	11	25	33	36	36	23	26	58
Number of Eggs Laid:	747														
Number of Eggs Hatched:	567														
Number of Young Fledged:	396														

TABLE 15
Computation of Tree Swallow Clutch Size

<i>Year</i>	<i>Completed Clutches</i>	<i>Eggs Laid</i>	<i>Average Size</i>
1966	1	5	5.00
1967	4	23	5.75
1968	6	25	4.16
1969	7	33	4.71
1970	9	44	4.99
1971	12	63	5.25
1972	11	57	5.09
1973	10	54	5.40
1974	12	57	4.66
1975	15	77	5.13
1976	10	48	4.80
1977	12	67	5.58
1978	8	41	5.12
1979	9	45	5.00
1980	17	82	4.82

Average clutch size for 15 years: 5.03.

TABLE 16
Tree Swallow Breeding Season Based on Clutch Completion

<i>Year</i>	<i>May 10-19</i>	<i>May 20-29</i>	<i>May 30- June 8</i>	<i>June 9-18</i>	<i>June 19-28</i>
1966			1		
1967			4		
1968		3	2		1
1969		5	3		
1970	3	4	1	1	
1971	2	7	2	1	
1972		7	2	2	
1973		2	6	3	
1974	2	8	1	3	
1975	2	7	3	1	
1976	1	5	3	2	
1977	5	6	1		1
1978	2	2	4	2	
1979		1	6	2	
1980	3	10			1
TOTAL	20	67	39	17	3
Percentages of Clutches Completed in Each 10-day Period	13.81	46.53	27.08	11.8	.69

TABLE 17
Black-capped Chickadee Nesting Success

	<i>Pairs</i>	<i>Broods</i>	<i>Eggs Laid</i>	<i>Eggs Hatched</i>	<i>Percent</i>	<i>Young Fledged</i>	<i>Percent</i>
1967	3	2	22	11	50	11	100
1968	4	2	24	11	45	11	100
1969	1	0					
1970	1	1	9	4	44	4	100
	(2 nestings)						
1971	2	0	5	0			
1972	1	0	0				
1973	4	2	23	12	52	12	100
1974	1	1	7	4	57	1	25
1975	1	0					
1976	0						
1977	1	0					
1978	0						
1979	1	1	6	6	100	6	100
1980	2	2	12	10	93	10	100
TOTAL	22	11	108	58		55	

Causes of Failure:
House Wren: 28 eggs; two other nest interruptions
Human Interference: Three young and 11 eggs
Bees: One interruption
Eight eggs failed to hatch.
Three eggs or young disappeared from clutch of seven.

References

- Campbell, M.
1974 Bluebird nesting study. *Indiana Audubon Quarterly* 53:10-13; 54:86-90.
- Clapp, R. B.
1974 Review of "Prolonged incubation period for an Eastern Bluebird," by C. Pindowski. In *Inland Bird Banding News* 46:15-19.
- Goldman, P.
1975 Hunting Behaviour of Eastern Bluebirds. *Auk* 42:798-801.
- Hartshorne, J. M.
1962 Behavior of the Eastern Bluebird at the nest. *The Living Bird* 1:131-149.
- Johnson, C. W.
1932 Notes on Protocalliphera during the summer of 1931. *Bird Banding* 3:26-29.
- Kibler, L. F.
1969 The establishment and maintenance of a bluebird nest-box project. *Bird-Banding* 40:114-132.
- Krieg, D. C.
1971 *The Behaviour Patterns of the Eastern Bluebird*. N.Y. State Museum and Science Service, Bull. no. 415.
- Laskey, A. R.
1939 A study of nesting Eastern Bluebirds. *Bird-Banding* 10:23-32.
- Mason, E. A.
1944 Parasitism by Protocalliphera and management of cavity-nesting birds. *Journal of Wildlife Management* 8:232-247.
- Musselman, T. E.
1935 Three years of Eastern Bluebird Banding and Study. *Bird-Banding* 6:117-125.
- Musselman, T. E.
1939 The effect of cold snaps upon the nesting of the Eastern Bluebird. *Bird-Banding* 10:33-35.
- Peakall, D. B.
1970 The Eastern Bluebird: its breeding season, clutch size and nesting success. *The Living Bird* 9:239-256.
- Pinkowski, B. C.
1979 Annual productivity and its measurements in a multibrooded passerine, the Eastern Bluebird. *Auk* 96:562-572.
- Thomas, R. H.
1946 A Study of Eastern Bluebirds in Arkansas. *Wilson Bulletin* 58:143-183.
- Zeleny, L.
1976 *The Bluebird*. Indiana University Press, Bloomington.